Wetting Front

Water Management Research Unit Newsletter

Vol. 3, No. 1 | USDA-ARS Conservation and Production Research Laboratory | May 1999

P.O. Drawer 10 ! Bushland, Texas 79012-0010 U.S.A.

(806) 356-5724 ! FAX (806) 356-5750 ! 2300 Experiment Station Road

LEPA vs. SPRAY SPRINKLER IRRIGATION . . .

by Arland Schneider

Should I equip my new center pivot with LEPA or spray sprinkler devices? Should I convert my existing spray heads to LEPA? These questions are commonly asked by owners of center pivot irrigation systems. In answering these questions, it is helpful to compare the application efficiency and uniformity of the two sprinkler methods. Application efficiency is the percent of applied water beneficially used by the crop. Beneficial use includes water stored in the plant root zone plus any droplet or crop canopy evaporation that offsets crop water use. Sprinkler uniformity can be expressed several ways, but in this evaluation, we will use the uniformity coefficient first proposed by J. E Christiansen in 1942. The uniformity coefficient can range from 0.0 to 1.0, with a minimum desirable uniformity of about 0.85 for a center pivot irrigation system. Both the application efficiency and uniformity coefficient are affected by the depth of irrigation. The information presented here is for a 1-inch sprinkler application which is representative of most center pivot irrigations.

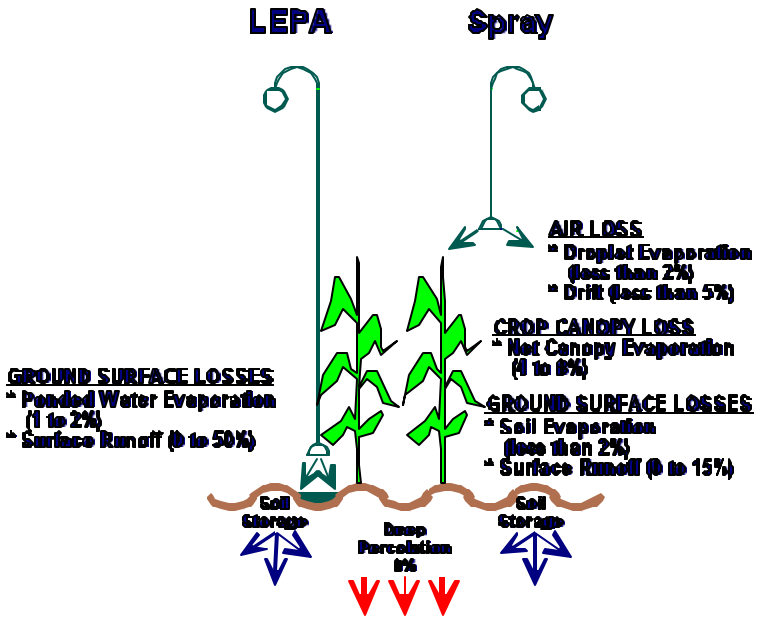

Figure 1. Illustration of the water loss pathways for LEPA and spray application methods for sprinkler irrigation.

Application efficiency of the LEPA and spray sprinkler methods is reduced by the sprinkler water losses illustrated in Fig. 1. For LEPA, the only two losses are evaporation of ponded water and surface runoff. Evaporation of ponded water will be small, especially for alternate furrow application, and will normally be 2% or less. Ideally, the surface runoff loss is zero which results in a LEPA application efficiency approaching 98%. Zero runoff, even for flat slopes, will require basin tillage with furrow diking, implanted reservoir tillage, or large amounts of crop residues. In reality, surface runoff from LEPA can be quite large, and it has been measured by several researchers to be as much as 50% of the applied water. Surface runoff from LEPA will either be redistributed within the irrigated field or lost as runoff from the field. With deficit or less than full irrigation to meet the crop water use, the redistributed water may be utilized by the crop. With full irrigation to meet all the crop water needs, the

INSIDE

redistributed water will either be lost as deep percolation below the crop root zone or remain as excess water in the crop root zone at harvest.

As illustrated in Fig. 1, spray irrigation is subject to water losses in the air and from the crop canopy as well as from the soil surface. Water losses in the air and from the crop canopy are difficult to measure directly, but indirect measurements and theoretical calculations provide the loss numbers in Fig. 1. Droplet evaporation is limited by the energy available to convert water from a liquid to a vapor and generally will be less than 2%. Droplet evaporation may offset crop water use, but this amount is also difficult to measure or calculate. Drift losses can be potentially large too, but with careful selection of serrated spray plates, they can be limited to less than 5%. Crop canopy net evaporation loss is the wetted crop canopy evaporation less the crop transpiration reduction offset (both from the wetted foliage and higher humidity). Several researchers have calculated or measured this loss. The upper limit is about 10%, and a normal range for spray irrigation is 4 to 8%. Spray irrigation is also subject to surface runoff but not to the same extent as LEPA irrigation. Field measurements by researchers suggest that spray runoff will unlikely exceed 15% except on slopes exceeding 3 to 5%. Soil surface evaporation during the irrigation event would be small and would unlikely exceed 1% of the applied water.

Combining the various water losses provides a range of application efficiencies to be expected for the LEPA and spray sprinkler methods. For alternate furrow LEPA irrigation, application efficiencies of 95 to 98% are easily obtainable if surface runoff is zero. When runoff occurs, application efficiency is difficult to measure or estimate, but the measurements have shown that it can be reduced to 80% or less. For spray irrigation of a crop with a full canopy, application efficiencies in the range of 90 to 92% are attainable with zero surface runoff.

The spray application efficiency reported here is based on measurements other than those made with catch cans. Evaporation from a catch can, itself, can be mistaken for droplet evaporation and drift loss. Also, wind tunnel tests show that the amount of water collected by catch cans can be reduced as much as 15% when wind speeds exceed 7 mph. For this reason, the author believes that measurement techniques such as chemical tracers, weighing lysimeters, and energy balance modeling provide more accurate application efficiency estimates for modern spray irrigation.

For the LEPA method and to some extent the spray method, sprinkler water distribution depends on the movement of the center pivot system as well as on the sprinkler device. Uniformity along the pipeline depends primarily on the spacing, discharge, and pattern of the sprinkler device. Uniformity in the direction of travel is highly dependent on how uniformly the irrigation system moves. The end tower of a center pivot system follows a fixed on/off cycle, and the towers near the end tower tend to follow this cycle. In the interior of the system, however, tower movement is random and start and stop times in the 1 to 3 minute range have been measured. As a result, uniformity coefficients in the direction of travel are largest near the pivot and end tower and smallest near the center of the irrigation system.

With the small wetted pattern of LEPA irrigation, the effect of the irrigation system movement on sprinkler uniformity is much larger than for spray irrigation. Uniformity coefficients in the range of 0.1 to 0.5 have been measured in the interior of center pivot systems with collectors 1 to 2 feet long. For the same systems and type of measurement, uniformity coefficients near the end tower exceed 0.90. The low “application” uniformity can be improved by impounding water from several stop-and-go cycles with furrow dikes or basin tillage. With basin length in the range of 6 to 12 feet, the uniformity coefficients can then be raised to about 0.80 in the interior of the system. With longer basins, the effect of slope and soil infiltration variability begins to reduce the uniformity. For spray irrigation, the effect of system movement is smaller and uniformity coefficients would typically be reduced from about 0.90 at the end of the system to about 0.75 near the center of the system.

In general, sprinkler application with LEPA will be more uniform than spray along the center pivot pipeline and may be less uniform in the direction of travel. Along the pipeline, the uniformity coefficient of the LEPA method can exceed 0.95 and is only limited by the finite number of nozzles available to the designer. In the direction of travel, the uniformity coefficient with furrow dikes can be raised to about 0.80 in the interior of the system and to about 0.90 near the end tower. For a well-designed spray system, the uniformity coefficient can be about 0.85 along the pipeline and in the 0.80 to 0.85 range in the direction of travel.

Wetting Front is published semi-annually (May and November) and distributed by the USDA-ARS, Conservation and Production Research Laboratory, Water Management Research Unit, P.O. Drawer 10, Bushland, TX 79012-0010.

Editor: Dr. Terry A. Howell, P.E.
USDA-ARS
P.O. Drawer 10
Bushland, TX 79012-0010
e-mail: tahowell@ag.gov
Phone: (806) 356-5746
Fax: (806) 356-5750
Shipping: 2300 Experiment Station Road

Selection of the LEPA or the spray sprinkler methods requires careful evaluation of the water loss components illustrated in Fig. 1 and the factors affecting uniformity. When irrigating grain crops for maximum yields, the application efficiency advantage of the LEPA method can be lost by the increased potential for runoff. In two-year cropping comparisons with corn, grain sorghum, and wheat, maximum grain yields with the LEPA and spray sprinkler methods have been essentially equal with similar water use. For deficit or less than full irrigation, the runoff potential diminishes, and yields from the same amount of water are often larger with the LEPA method than with the spray method. In the Southern Great Plains, grain sorghum yields as large as 8,000 lb/ac have been obtained with 5 inches of irrigation water supplementing timely rainfall. Similarly, cotton lint yields of 1,000 or more pounds per acre have been obtained with 4 to 6 inches of water applied by LEPA. If runoff is controlled, large preplant or early season irrigations can also be made more efficiently with LEPA than with spray. When irrigating bare soil, droplet evaporation from the spray method cannot offset any crop water use, and wetting the entire soil surface is inefficient for soil water storage.

References:

Howell, T. A., A. D. Schneider and J. A. Tolk. 1991. Sprinkler evaporation losses and efficiency. pp. 69-89. *In Proc. Central Plains Irrigation Short Course*, Manhattan, KS: Kansas State Univ. Cooperative Ext. Ser.

Schneider, A. D. and T. A. Howell. 1999. LEPA and spray irrigation for grain crops. Amer. Soc. of Civil Engr. J. of Irrig. and Drain. Engr. (Accepted for Publication)

Schneider, A. D. 1999. Efficiency and uniformity of the LEPA and spray sprinkler methods. Trans. of the ASAE (Submitted for publication).

THE NEW ARS NATIONAL PROGRAM FOR IRRIGATION RESEARCH . . .

by Terry Howell

All the ARS National Programs are being updated and rewritten. The Agricultural Research Service (ARS) is the principal research agency of the U.S. Department of Agriculture, and it is charged with extending the nation's scientific knowledge across a broad range of program areas that affect the American people on a daily basis. The agency's work falls into three main categories:

- Animal Production, Product Value, and Safety
- Natural Resources and Sustainable Agricultural Systems
- Crop Production, Product Value, and Safety

Irrigation and **Drainage** research is a component of the Natural Resources and Sustainable Agricultural Systems under the National Program 201 on *Water Quality and Management* (WQM).

Irrigation and Drainage Management - Existing and future water resources for irrigation are projected to decline even further, which further emphasizes the need to improve irrigation and drainage practices to enhance water quality and sustain American food production for strategic national economic and social benefits. Innovative irrigation and drainage techniques and management are required that can improve water quality, reduce soil erosion, conserve water, and reduce energy requirements while enhancing and sustaining crop production and water use efficiency. Advanced technologies, like precision agriculture, site-specific management, remote sensing, and decision support systems, are needed to address the water quantity and quality needs in irrigated agriculture.

A national program workshop entitled *Irrigation and Drainage in Harmony with the Environment* was held May 27-28, 1998, in Fort Collins, CO, to initiate the development of the new ARS irrigation and drainage national research program. The purpose of the workshop was to solicit input on research issues from customers, stakeholders, and partners and to establish research teams across the Nation.

Three breakout sessions were held and facilitators guided the session groups. In the first session, six groups identified 272 needs or issues. In the second session, each group identified their ten most important issues (60 total). In the third session, the six groups were asked to consolidate the needs around fewer than ten topics. From these results, the ARS leadership team developed nine themes for which national research teams could be established. The nine themes were grouped around three categories:

- Crop Production Management Systems
- Water Quantity Technologies
- Water Quality & Environmental Impacts

A follow-up meeting of the ARS Irrigation and Drainage Leadership Team was held on August 25- 27, 1998, in Beltsville, MD, to draft descriptions of each problem, approaches, goals (intermediate and long-term), impacts, and to identify the linkages with other ARS national programs, programs in WQM, and programs within the irrigation and drainage component.

The identified research themes and team coordinators are listed below:

Water Quality & Management National Program
Irrigation and Drainage Component
Field Coordination Team
Team Coordinator: Shirley Rish (Phoenix, AZ)

Crop Production Management Systems

- *Integrated Crop Production* – Tom Trout (Fresno, CA)

- *Precision Agriculture* – Dale Heermann (Ft. Collins, CO)

Water Quantity Technologies

- *Water Conservation Management* – Bert Clemmens (Phoenix, AZ)
- *Irrigation in Humid Areas* – Carl Camp (Florence, SC)

Water Quality & Environmental Impacts

- *Waste Water Reuse* – Terry Howell (Bushland, TX)
- *Erosion on Irrigated Lands* – Bob Sojka (Kimberly, ID)
- *Environmental Quality Impacts* – Dale Westermann (Kimberly, ID)
- *Salinity Management* – Mike Shannon (Riverside, CA)
- *Drainage Management* – Jim Fouss (Baton Rouge, LA)

These activities are chronicled in the "Water Quality and Management National Program Component Action Plan and Workshop Report," which you may request from

Sharon D. Drumm
USDA-ARS-NPS
5601 Sunnyside Avenue
Beltsville, MD 20705-5140
(301) 504-4731
(301) 504- 6231 (fax)
sdd@ars.usda.gov (e-mail)

IAEA CONSULTANTS SUPPORT CONTINUED USE OF THE NEUTRON MOISTURE METER . . .

by Steve Evett

In November 1998, the International Atomic Energy Agency (IAEA) convened a three-day meeting in Vienna, Austria of five scientific experts in soil water content measurement and in research involving new methods of water content measurement. Scientists were invited from Australia, Canada, France, Spain, and the United States to discuss methods including the venerable neutron moisture meter (NMM), and newer electronic methods including time domain reflectometry (TDR) and frequency domain (FD) or capacitance (CP) methods. Participants were selected because each had extensively used and conducted research on the NMM, TDR, and FD or CP methods. The TDR, FD, and CP methods all rely on the relatively high permittivity or dielectric constant of water, which is about 80, compared with the relatively low permittivity of soil materials (approximately 3 to 5). They all use some electronic measurement of the effect of increased water content on the bulk permittivity of the soil. The NMM relies on the interaction of neutrons, emitted from a radioactive source, with the hydrogen in the soil. Hydrogen in the soil is proportional to the water content of the soil. In the NMM method, relatively high energy neutrons are thermalized through repeated interaction with hydrogen atoms and the thermalized neutrons detected. In present day NMMs, the radioactive source is an Am241-Be pellet, doubly encapsulated in welded stainless steel containers. The IAEA routinely recommends the use of the NMM in its cooperative agricultural research programs around the world, and often supplies the NMM and appropriate training in its assistance programs. The two major manufacturers of NMMs world-wide are in the U.S. – Troxler Electronics Laboratories, Inc., Research Triangle Park, NC; and Campbell Pacific Nuclear International, Martinez, CA.

Each participant wrote and presented a chapter for publication in an upcoming IAEA TEC-DOC. These presentations and discussions led to several conclusions. First, the neutron moisture meter was recognized as being still the most widely applicable, well-researched, non-destructive method of profile soil water content measurement. Its continued use was recommended. Second, discussions made clear that the NMM has been demonstrated to be safe and reliable in its over 40 years of use around the world. In fact, there are no known breaches of the doubly encapsulated radioactive sources used in these meters. This was despite such bizarre and severe industrial accidents including a meter falling from a 10-story building and meters crushed by heavy earth moving equipment and road compactors. Included in these findings are the gamma soil density meters commonly used in engineering. In the U.S., some NRC licensees no longer use personal dosimetry for the NMM because dosimetry results are routinely lower than detection limits. Over the past several years at Bushland, where we do use dosimeters, we have had several positive dosimeter reports, all of which proved to be false. Either the badge in question was a visitor badge that had never been used, or the report was for the winter months when the badge had not once been used as verified by sign-out records. Meeting participants agreed that regulations and paperwork related to the use of NMMs should be minimized.

The participants also agreed that there was no clear disposal path for radioactive sources from older, surplus meters. And, they called for efforts to facilitate recycling of these sources. In fact, sources from newer models (going back to the later '70s or early '80s) of the NMM can be recycled into new gauges by at least one U.S. manufacturer, Campbell Pacific Nuclear International. At Bushland, we have recycled three sources from older model 503DR gauges into new gauges in the past year with this procedure.

The newer TDR, FD, and CP methods were recognized as having some advantages of electronic recording, unattended operation, and small measurement volume (when that is desired) that may be useful in particular situations. Their use was encouraged where applicable, but attention was drawn to the many disadvantages of the relatively small measurement volumes typically obtained with these methods. In most cases, many measurements or probes must be used to obtain water contents that are as representative of the field soil water content as those obtained with the NMM. To date, none of the electronic methods commercially available is as good as the

NMM for soil profile water content measurement under most field conditions.

THE ATUT PROJECT . . .

by Steve Evett and Rick Todd

A team of U.S. and Egyptian scientists is just finishing the second year of a bilateral U.S.-Egyptian research project investigating crop water use, water use efficiency, and irrigation management at Ismailia, in the Eastern Desert of Egypt, and at Bushland, TX, in the Southern High Plains of the U.S. The three-year, USAID funded project through USDA-FAS involves researchers from the USDA-ARS, Conservation and Production Research Laboratory at Bushland and their counterparts with the Soil, Water, and Environment Research Institute at Giza, Egypt (see bottom of article). The project, titled "Water Requirements and Management of Maize under Drip and Sprinkler Irrigation," uses the soil water balance, measured by weighing lysimeters and a time domain reflectometry (TDR) soil water content measurement system, to establish crop water use and water use efficiencies for corn, wheat, and alfalfa under drip and sprinkler irrigation at Ismailia. From Feb. 16 to 24, 1999, Dr. Rick Todd visited the Egyptian research site at Ismailia, Egypt, near the Suez canal in Egypt's Eastern Desert (Fig. 1). From Feb. 26 to Mar. 12, Drs. Sadek El-Rais (Fig. 1) and Wafai El-Husainey visited us at Bushland to work on weather, weighing lysimeter, and soil profile water content data collected in 1998 at Ismailia.

At Bushland, alfalfa and turf grass are grown on weighing lysimeters under sprinkler and subsurface drip irrigation, respectively, to establish reference evapotranspiration (ET) data and to test Penman-Monteith (PM) reference ET equations used widely for irrigation scheduling. Preliminary results from the Bushland studies, reported at the ASAE International Meeting in Orlando, FL, last summer, indicate the PM equation under-predicts grass ET in the windy, hot, dry, and advective environment at Bushland (Howell et al., 1998). In contrast, Penman-Monteith estimates of alfalfa ET were very good, even when daily ET rates reached 16 mm (Evett et al., 1998; Todd et al., 1998). In addition to the ET work, the Bushland Team is researching an automatic drip irrigation control system that uses the crop canopy temperature as a key input for control. Working with both surface and subsurface drip, the control system, developed at the ARS Plant Stress Laboratory, Lubbock, TX, uses a crop-specific threshold temperature and region-specific threshold time to determine whether to irrigate on a daily basis. The system has worked with two years of corn and two years of soybean and is in its third year of tests with corn. Results indicate the potential for hands-off irrigation, and the ability to decide in advance where to end on the irrigation vs. yield curve.

The work in Egypt is part of the Egyptian government's efforts to introduce irrigation to the New Lands that are being developed in the Eastern and Western Egyptian Deserts. Water for the projects flows hundreds of kilometers from the Aswan dam through concrete lined canals to the New Lands. Soils in these areas are deep sands, ranging from fine to coarse in texture, and require careful irrigation management for successful cropping. The TDR system was installed at Ismailia in 1998, and was custom designed at Bushland as a solar-powered, autonomous system using a low-power PC-104 embedded computer and multiplexers developed at Bushland and now sold by Dynamax, Inc, Houston, TX (Evett, 1998ab). The TDR probes were also designed and built at Bushland because probes ranging in length from 0.5 to 1.5-m long are not commercially available. The newly developed technologies will likely be commercialized and made available to the public in the near future via a Cooperative Research and Development Agreement. Three profiles in each of two fields were instrumented with TDR probes to a depth of 3 m.

Figure 1. Egyptian staff examining the net radiometer installation over the alfalfa weighing lysimeter at Ismailia, Egypt. Second from right is Dr. Sadek El-Rais. Second from left is Mr. Walid, who does much of the on-site data collection and calibrated the weighing lysimeters in March 1998.

The TDR system ran unattended from Aug. 12, 1998, to Jan. 11, 1999. Water content data at six of eleven depths measured for profile #4 in the south lysimeter field at Ismailia are illustrated in Fig. 2. To avoid clutter, only the top three depth intervals and the bottom three depth intervals measured are shown. The data cover the latter part of a maize irrigation season that was discontinued on Sept. 3 (day 246), a fallow

period from Sept. 3 to Nov. 7, and the first part of a faba bean irrigation season after irrigations were resumed on Nov. 7 (day 311). A large irrigation on day 237 allowed the wetting front to be followed. It arrived at the 0.75 to 1.5-m depth interval on day 239, at the 1.5 to 2.25-m depth interval on day 241, and at the 1.5 to 3.0-m depth interval on day 244. Maize was harvested on Sept. 9 (day 252). During the fallow period, the three measurements near the soil surface approached the air dry value for the coarse sand at Ismailia. The three deep measurements approached steady values that were different depending on the depth. The 0.75 to 1.5-m layer dried more than the deeper layers, probably due to water extraction by corn roots, which can reach to 1.5-m depth. The two deepest measurements probably approached the "field capacity" for this soil, which can be estimated at about 0.06 $m^3 m^{-3}$. Note the narrow range of water contents, which almost

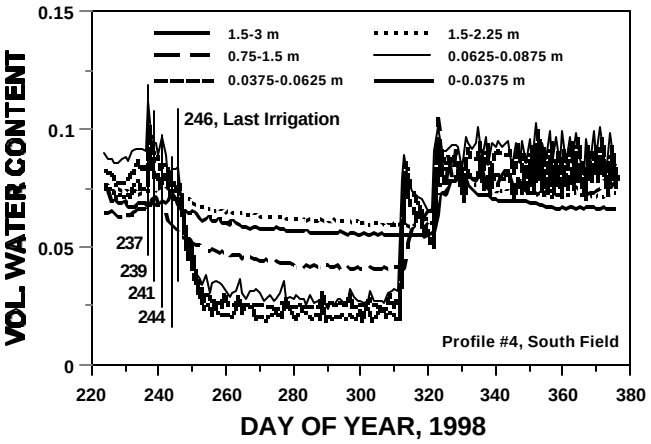

Figure 2. Water contents at six of eleven depths measured for profile #4 in the south lysimeter field at Ismailia, Egypt. Data began on August 12, 1998 and ended on January 11, 1999. Maize irrigations were discontinued on Sept. 3 (day 246), and irrigations were resumed on Nov. 7 (day 311) prior to planting faba bean. A large irrigation on day 237 allowed the wetting front to be followed. It arrived at the 0.75 to 1.5 m depth interval on day 239, at the 1.5 to 2.25 m depth interval on day 241, and at the 1.5 to 3.0 m depth interval on day 244.

never exceed 0.10 $m^3 m^{-3}$, even when heavily irrigated. After day 344, faba bean was irrigated every other day, causing the zig-zag pattern in the water contents at the upper three depths. Fluctuations in water content were more modest for the deeper measurements. But, the quick rise in water content in the 0.75 to 1.5-m interval and the increase of water contents for the deeper measurements to well above "field capacity" are evidence of considerable deep percolation loss under the imposed irrigation regime.

Water storage in each of the three profiles measured with TDR in the south lysimeter field at Ismailia is shown in Fig. 3. Storage changed by about 110 mm over the 3 m profile after the fallow period was broken by irrigations beginning on Nov. 7 (day 311). This is equivalent to a 0.037 $m^3 m^{-3}$ increase in bulk soil

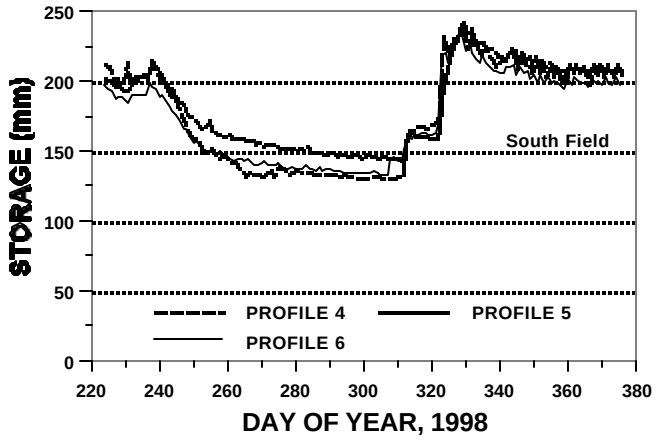

Figure 3. Water storage in each of three profiles measured with TDR in the south lysimeter field at Ismailia, Egypt. Data began on August 12, 1998 and ended on January 11, 1999. Maize irrigations were discontinued on Sept. 3 (day 246), and irrigations were resumed on Nov. 7 (day 311) prior to planting faba bean.

water content. The negative of the change in storage, ΔS (mm), is a large component of evapotranspiration, ET (mm), as determined by the soil water balance

$$ET = -\Delta S + P + I - R + F \quad [1]$$

where P and I are precipitation and irrigation (mm), R is runoff (mm), and F is flux (mm) across the bottom of the soil volume, considered to be a right rectangular prism 3-m deep and 1 m^2 in horizontal surface area. We take F as positive when flux is

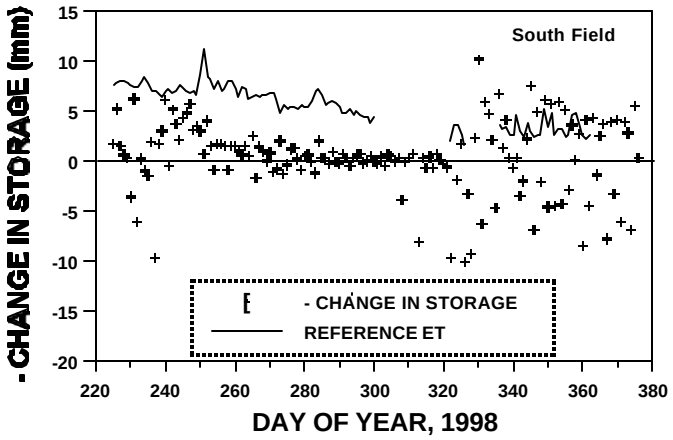

Figure 4. The negative of change in storage as measured by TDR in three 3-m profiles in the south lysimeter field at Ismailia, Egypt, and the Penman-Monteith alfalfa reference ET computed from Ismailia weather data using methods of Allen et al. (1994) and Jensen et al. (1990).

upward across the lower boundary of this control volume. For this discussion we will disregard P, which was minor during the period, and I, for which data are unavailable at this writing. Figure 4 shows the component of ET that is due to change in storage compared with daily alfalfa reference ET computed using methods of Allen et al. (1994) and Jensen et al. (1990). Large negative values of -) S in Fig. 4 are due to irrigations. The fact that values of -) S approached that of reference ET in the period around day 240, even though heavy irrigations were applied during this period, is evidence of the importance of deep percolation losses across the lower boundary of the control volume. Deep percolation is also evident in the many values of -) S that are higher than reference ET in the period after irrigations for faba bean were started on Nov. 7 (day 311).

The values of alfalfa reference ET shown in Fig. 4 will seem low to many readers, particularly considering that Ismailia is in the Eastern Desert of Egypt. However, the climate at Ismailia is less aggressive than that at Bushland, TX in most respects. The climate at Ismailia, Egypt, and Bushland, TX during the growing season in 1998 (from Day of Year 111 to 272) are contrasted in Table 1. Both Ismailia and Bushland received unusually low precipitation. Solar radiation at Ismailia (30°36´N) and Bushland (35°11´N) were similar on cloudless days because the two sites are at similar latitudes. Bushland experienced more cloudy days, so the mean daily solar radiation was about 7% greater at Ismailia than at Bushland. Although air temperature was generally warmer at Ismailia than Bushland, the air humidity at Bushland was drier, with dew point temperatures consistently lower than at Ismailia (Fig. 5A). The continental climate of Bushland is dominated by dry air masses from the desert southwest during the growing season, while Ismailia often experiences moist, maritime air masses from the Mediterranean Sea. Bushland had 70% greater mean wind speed than Ismailia (Fig. 5B). Ismailia experiences a predominate sea breeze too.

Table 1. Climatic variables at Ismailia, Egypt and Bushland, TX, from Day of Year 111 to 272 , 1998. Numbers in parentheses are the standard deviation of a mean.

Site	Total Precip.	Solar Rad.	Air Temp.	Dew Point Temp.	Wind Speed
	mm	MJ m^{-2} d^{-1}	------ EC ------		m s^{-1}
Ismailia, Egypt	3.3	25.8 (3.8)	26.4 (3.1)	17.2 (3.4)	2.3 (0.6)
Bushland, TX	63.0	24.0 (5.0)	22.2 (4.7)	10.9 (5.0)	3.9 (1.4)

The cooperative project has led to increased knowledge of crop water use and water use efficiency both in the U.S. and in Egypt. Expectations of high ET rates in the Egyptian Eastern Desert were not met. Alfalfa ET rates there have been consistently less than those at Bushland (data not shown). The TDR water content measuring system has reliably collected data on soil water storage and change in storage needed to solve Eq. [1] for ET. Data from the TDR system also illustrate the water relations of the coarse sandy soil at Ismailia and were key to discovering deep percolation losses that can now be addressed by changes in irrigation management.

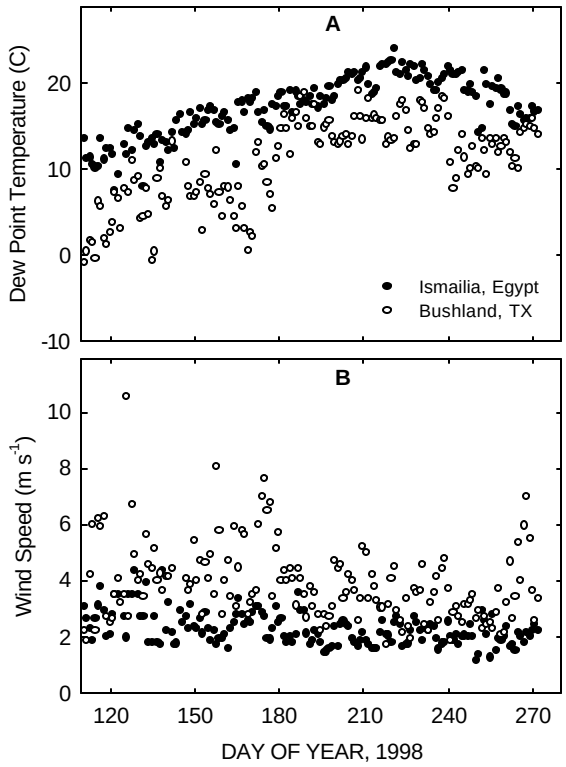

Figure 5. Dew point temperatures and wind speeds for the maize growing season at Ismailia, Egypt and Bushland, TX, in 1998.

The authors wish to thank all their Egyptian colleagues for the many long hours of work and always congenial reception during their stays in Egypt.

References:

Allen, R.G., M. Smith, A. Perrier, and L.S. Pereira. 1994. An update for the calculation of reference evapotranspiration. ICID Bulletin 43(2):35-92.

Evett, S.R. 1998a. Coaxial multiplexer for time domain reflectometry measurement of soil water content and bulk electrical conductivity. Trans. ASAE 41(2):361-369.

Evett, S.R. 1998b. The TACQ program for automatic measurement of water content and bulk electrical conductivity using time domain reflectometry. Presented at the 1998 Annual International Meeting Sponsored by ASAE. ASAE Paper No. 983182. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

Evett, S.R., T.A. Howell, R.W. Todd, A.D. Schneider,and J.A. Tolk. 1998. Evapotranspiration of irrigated alfalfa in a semi-arid environment. Presented at the 1998 Annual International Meeting Sponsored by ASAE. ASAE Paper No. 982123. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

Howell, T.A., S. R. Evett, A.D. Schneider, R.W. Todd, and J.A. Tolk. 1998. Evapotranspiration of irrigated fescue grass in a semi-arid environment. Presented at the 1998 Annual International Meeting Sponsored by ASAE. ASAE Paper No. 982117. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

Jensen, M.E., R.D. Burman, and R.G. Allen. 1990. Evapotranspiration and irrigation water requirements. ASCE Manuals and Reports on Engineering Practice No. 70, Am. Soc. Civil Engr., New York, NY. 332 p.

Todd, R.W., S.R. Evett, and T.A. Howell. 1998. Latent heat flux of irrigated alfalfa measured by weighing lysimeter and Bowen ratio-energy balance. Presented at the 1998 Annual International Meeting Sponsored by ASAE. ASAE Paper No. 982119. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

Cooperative U.S.-Egyptian Research on Water Requirements and Management of Maize under Drip and Sprinkler Irrigation

Cooperating Institutions and Investigators:

Dr. Steven R. Evett, Soil Scientist
Dr. Terry A. Howell, Research Leader, Agricultural Engineer
Dr. Arland D. Schneider, Agricultural Engineer
Dr. Richard W. Todd, Plant Physiologist

Water Management Research Unit
Conservation & Production Research Laboratory
USDA-ARS
2300 Experiment Station Road
Bushland, TX, U.S.A
Tel: 806-356-5775
FAX: 806-356-5750
E-mail: srevett@ag.gov
Internet: http://www.cprl.ars.usda.gov

Dr. Ahmed Taher A. Moustafa, Deputy Director
Dr. Wahba A. Abou-Zeid, Head of Research, Soil Physics and Chemistry
Dr. Wafai El-Husainy
Dr. Sadek El-Rais

Soils, Water and Environment Research Institute
Agricultural Research Centre, Ministry of Agriculture
9 El Gamaa Street
Giza, Egypt
Tel: 202-572-0608
FAX: 202-572-0507
E-mail: sweri@esic.claes.sci.eg

Newsletter . . .

The *Wetting Front* newsletter is designed to foster technology transfer from our research to industry and to agricultural producers in the Southern High Plains and to improve communications with our stakeholders and partners. For actions or corrections to our mailing list, contact Mrs. Carole Perryman by fax [(806) 356-5750], e-mail (cperryma@ag.gov), phone [(806) 356-5749], or mail [USDA-ARS, P.O. Drawer 10, Bushland, TX 79012]. The *Wetting Front* can also be found on the WWW at http://www.cprl.ars.usda.gov/wmru/wfront.htm. Any suggestions or comments are welcome.

Awards and Recognitions . . .

Don Dusek, agronomist, was awarded the 1999 Support Scientist of the Year on March 31, 1999, at the ARS Southern Plains Area Leadership Conference in Stuttgart, AR.

The **NP-PET Network Team** received a Texas Environmental Excellence Award from the Texas Natural Resource Conservation Commission in the agriculture category on May 4, 1999, in Austin, TX. They were also recognized by the Governor of Texas, George W. Bush, and the Texas House of Representatives (HR 823 passed on May 4, 1999). The award was co-shared by each agency – Texas Agricultural Experiment Station, Texas Agricultural Extension Service, and the USDA-ARS. The ARS team members recognized were **Don Dusek** and **Terry Howell**.

Jim Cresap and **Brice Ruthardt** were promoted.

Keith Brock received an "outstanding" annual performance rating and **Karen Copeland**, **Jim Cresap**, **Brice Ruthardt**, and **Carole Perryman** all received "superior" annual performance ratings and each will receive a performance award.

Grant News . . .

Judy Tolk submitted the research proposal "Carbon Sequestration and Release of Southern High Plains Agriculture" along with Thanh Dao to the USDA-NRI Competitive Grants Program. [$844,650]

Judy Tolk submitted the research proposal "Water Use Efficiency of Irrigated Soybean Grown in Three High Plains Soils" to the Texas Soybean Board. [$20,000]

Steve Evett, **Terry Howell**, and **Arland Schneider** submitted the research proposal "Automatic Irrigation Scheduling and Control Using Single Time of Day Canopy Temperature Measurements" to the USDA-NRI Competitive Grants Program. [$235,731]

Charles Rush, Giovanni Piccinni, **Steve Evett**, and Dan Upchurch submitted the proposal "Optimization of Crop Water Use Efficiency in Pathogen Infested Soils" to the USDA-NRI Competitive Grants Program. [$153,325]

Upcoming Events, Meetings, and Presentations . . .

June 1, 1999 – "Radiation Safety Training, Bushland, TX.
Contact: Steve Evett, (806) 356-5775 or srevett@ag.gov.

FIELD DAYS:

June 9, 1999 – Seminar "Large Scale Swine Operations," North Plains Field Station, Etter.
Contact: Dr. John Sweeten, (806) 359-5401 or j-sweeten@tamu.edu.

June 16, 1999 – North Plains Field Day at Etter.
Contact: Thomas Marek (806) 359-5401 or t-marek@tamu.edu.

Sept. 1, 1999 – Field Day at Bushland.
Contact: Dr. Louis Baumhardt (806) 356-5766 or lbaumbar@ag.gov.

UPCOMING MEETINGS:

June 15-18, 1999 – Texas Council of Chapters, Soil and Water Conservation Society (TC-SWCS) Meeting "Water for Texans" (Inn of the Hills, Kerrvillle).
Contact: Texas Council SWCS, P.O. Box 648, Goliad, TX 77963; Leory Mikeska, (512) 645-3677; or Dr. Steve Evett, (806) 356-5775 or srevett@ag.gov.

June 16, 1999 – "Techniques for Irrigation Management in the 21st Century: An Irrigation Technical Training Session" in conjunction with the TC-SWCS Meeting in Kerrville.
Contact: Dr. Steve Evett, (806) 356-5775 or srevett@ag.gov.

July 18-21, 1999 – ASAE/CSAE-SCGR Annual International Meeting, Toronto, Ontario, Canada.

Aug. 8-12, 1999 – ASCE International Water Resources Engineering Conference, Seattle, WA.

Aug. 19-20, 1999 – High Plains Beef Conference, TAMU Center, Amarillo.
Contact: Dr. Wayne Green (806) 359-5401 or w-green@tamu.edu.

Sept. 9-10, 1999 – Texas Animal Manure Management Conference, Red Lion Inn, Austin.
Contacts: Dr. Saqib Mukhtar (TAMU-College Station) (409) 458-1019 or mukhtar@tamu.edu. Dr. Brent Auvermann (TAEX-Amarillo) (806) 359-5401 or b-auvermann@tamu.edu.

Oct. 17-21, 1999 – Workshop on "Modernization of Irrigation Water Delivery Systems"and the seminar on "Concepts for Modernization of Water Delivery Systems," U.S. Comm. ICID (Phoenix, AZ).
Contact: Larry Stephens, U.S. Comm. ICID, 1616 Seventeenth St., #483, Denver, CO 80202, (303) 628-5430, (303) 628-5431 (fax), stephens@uscid.org, http://www.uscid.org/~uscid.

Oct. 28-29, 1999 – Texas Section of ASAE, Corpus Christi, TX.

Oct. 31-Nov. 4, 1999 – ASA/CSSA/SSSA Meeting, Salt Lake City, UT.

Nov. 7-9, 1999 – 50th Anniversary Meeting, Irrigation Association, Orlando, FL.

Feb. 8-10, 2000 – International Conference "Micro and Sprinkler Irrigation Systems" (New Delhi, India)
Contact: C.V.J. Varma, Organizing Secretary General IC-MSIS, Central Board of Irrigation and Power, Malcha Marg, Chanakyapuri, New Delhi 110 021, INDIA, 91-11-611-5984, 91-11-611-6347 (fax), cbip@nda.vsnl.net.in, http://www.cbip.org.

June 20-24, 2000 – "International Conference on the Challenges Facing Irrigation and Drainage in the New Millennium," U.S. Comm. ICID (Ft. Collins, CO).
Contact: Larry Stephens, U.S. Comm. ICID, 1616 Seventeenth St., #483, Denver, CO 80202, (303) 628-5430, (303) 628-5431 (fax), stephens@uscid.org, http://www.uscid.org/~uscid.

Sept. 30-Oct. 2, 2000 – "Water for Texas: 2000 and Beyond," Texas A&M University.
Contact: Jim Norwine, Dept. of Geosciences, TAMU-Kingsville, kfjrn00@tamuk.edu, http://www.tamiu.edu/water2000.

Nov. 14-16, 2000 – "4th National Irrigation Symposium," ASAE & IA, Phoenix, AZ.
Contact: Dr. Derrel Martin, Univ. of Nebraska, Biol. Systems Engr. Dept., L.W. Chase Hall, Lincoln, NE 68583-0726, (402) 472-1586, (402) 472-6338 (fax), dmartin@unlinfo.unl.edu.

UPCOMING PRESENTATIONS:

June 16, 1999 – TC-SWCS "Techniques for Irrigation Management in the 21st Century: An Irrigation Technical Training Session", Kerrville, TX.

Terry Howell, "Irrigation Scheduling" **[invited]**
Arland Schneider, "Conversion of Center Pivots to LEPA" **[invited]**
Steve Evett, "Soil Moisture Monitoring" **[invited]**

July 19, 1999 – ASAE/CSAE Meeting, Toronto, Ontario, CANADA.

Arland Schneider, "Runoff from LEPA and Spray Irrigation of a Slowly Permeable Soil"

Oct. 31-Nov. 4, 1999 – ASA/CSSA/SSSA Meeting, Salt Lake City, UT.

Steve Evett, "Corn Canopy Temperature Under Feedback Irrigation Control"
Judy Tolk, "Daily Evapotranspiration of Irrigated Grain Sorghum Grown in Three High Plains Soils"
Rick Todd, "Stomatal Response of Alfalfa to Increasing Water Deficit"
Terry Howell, "Enhancing WUE in Irrigated Agriculture" **[invited]**

Aug. 8-12, 1999 – ASCE Water Resources Engineering Conference, Seattle, WA.
Arland Schneider, "Efficiency of LEPA and Spray Irrigation"

Technology Transfer News . . .

CUSTOMER/CLIENTELE NEEDS:

Terry Howell, **Arland Schneider**, and **Steve Evett** met with Jerry Walker (Temple, TX), Peter Robinson (Little Rock, AR), Cleon Namken (Lubbock, TX), and Chris Stoner (Stillwater, OK) regarding irrigation technology, cooperation, and research needs on Jan. 14, 1999.

Steve Evett was invited by the USDA Radiation Safety Staff to help plan a Training of Trainers for Neutron Moisture/Density Gauge Radiation Safety. The training meeting was held May 5, 1999, in College Station, TX. At the meeting he presented a paper titled, "Achieving ALARA Through Scientific Efficiency in Neutron Probe Use". Steve will write training modules on Nuclear Gauge Design, Theory and Operation, and on Routine Cleaning, Lubrication, and Pre-Use Inspection for the course, which will be offered beginning in December, 1999.

Steve Evett was invited by the International Atomic Energy Agency to undertake a mission to Tashkent, Uzbekistan. Steve will be working with Dr. N. Ibramigov of the Uzbek National Cotton Growing Research Institute to evaluate water management practices and fertilizer use under the wheat-cotton rotation and impacts on soil water balance and irrigation water use efficiency. He will also assist in planning and installing a network of soil water content measurement sites using the neutron probe and will provide training in probe use and calibration.

MEDIA CONTACTS:

Terry Howell was interviewed on Feb. 23, 1999, by Harry Kline of *Southwest Farm Press* about expected irrigated cotton expansion on the northern Texas High Plains.

Steve Evett was interviewed on April 27, 1999, by Larry Lemmons, KFDA Channel 10 (CBS affiliate) of Amarillo, about weather measurements for reference evapotranspiration measurements used in the NP-PET Network. Video from the interview was shown twice in a series on National Water Conservation Week.

VISITORS:

Steve Evett and **Rick Todd** hosted Drs. Wafai El-Husainey and Sadek El-Rais from the Soils and Water Institute in Giza, Egypt from February 26 to March 12, 1999. They processed ATUT project data and trained on lysimeter, weather, and soil water content data processing. Both were trained in the use of the TACQ program to convert TDR wave forms into soil water contents. They also trained on determining soil water balances and computing reference evapotranspiration.

Steve Evett hosted a tour of the new Texas A&M Wheat Breeding Building on March, 25, 1999, for Den 7 of Pack 6 of the Cub Scouts of America.

Steve Evett trained and demonstrated TDR measurements of soil water to Bobbie McMichael, plant physiologist, and his technician both with USDA-ARS, Lubbock, TX, on April 2, 1999, and the use of the TACQ program for portable TDR readings.

Steve Evett and **Brice Ruthardt** trained Scott Van Pelt, soil scientist, and Charles Yates, soils technician, from USDA-ARS, Big Spring, TX, on construction and operation of a TDR system for soil water content measurement. The two-day training on April 13-14, 1999, covered construction of TDR probes and multiplexers, cabling and equipment setup, and use of the TACQ program to control the TDR system.

Steve Evett and Andy Cole provided a tour for the Leadership Amarillo class of irrigation, crop water use, and animal research on the station, April 15, 1999.

Steve Evett spoke on water content measurement using speed-of-light physics to a Gifted and Talented Class from Bushland ISD on April 16, 1999.

Steve Evett, **Terry Howell**, **Rick Todd**, **Arland Schneider**, and **Judy Tolk** presented several topics on irrigation for the West Texas A&M University Soil and Water Conservation Class on Thursday, April 22, 1999.

Steve Evett presented a talk on irrigation in the Southern High Plains to a class from Hereford High School on Friday, April 30, 1999.

SEMINARS/PRODUCER/CLIENTELE MEETING PRESENTATIONS:

Arland Schneider, **Terry Howell**, **Keith Brock**, **Brice Ruthardt**, and **Jim Cresap** attended a seminar sponsored by Senninger Irrigation, Inc. in Amarillo on Dec. 11, 1998, about sprinkler irrigation and new products.

Terry Howell attended the Pioneer Hybrid Corn Producers Meeting in Panhandle, TX, on Jan. 8, 1999.

Rick Todd, **Terry Howell**, and **Arland Schneider** attended the Central Plains Irrigation Workshop in Sterling, CO, Feb. 9-10, 1999.

Steve Evett presented soil moisture measurement using speed-of-light physics to four groups of students (54 students and four teachers) for the First-Step tour from Bowie Middle School, February 10, 1999.

Arland Schneider and **Terry Howell** attended the Kansas Water Conference in Manhattan, KS, Mar. 2-3, 1999.

Judy Tolk and **Rick Todd** presented talks at the Science Forum, sponsored by the Amarillo Center for Advanced Learning, about agriculture research in the region to interested area teachers and junior and senior high school students on April 8, 1999.

POPULAR MAGAZINE ARTICLES:

Howell, T., T. Marek, L. New, and D. Dusek. 1998. Weather network defends Texas water tables. Irrigation Business & Technology 6(6):16-20.

Bucks, D. 1999. ARS international research. Irrigation Business & Technology 7(1):40. **Steve Evett** wrote the section of the article – " U.S.-Egypt Irrigation Water Use and Efficiency Research."

CRADA/INTER-AGENCY COLLABORATION:

A CRADA is being finalized with a large swine producer in the Texas High Plains on "Sustainable Irrigation for Swine Production in the Southern High Plains" to identify water efficient cropping systems to utilize swine waste effluent in a semi-arid environment adapted for center pivot sprinkler irrigation to avoid impacting surface and ground water quality.

OTHER TECHNOLOGY TRANSFER ACTIVITIES:

Steve Evett judged a science fair at Arden Road Elementary on Nov. 4, 1998.

The Software area of the CPRL WWW site was upgraded with a new and more powerful version of the TACQ program for running a TDR system for soil water content measurement. Documentation was also upgraded with addition of information on wiring of cable testers for 12 VDC power and a circuit for controlling that power. A draft version of "Some Aspects of Time Domain Reflectometry (TDR), Neutron Scattering, and Capacitance Methods of Soil Water Content Measurement" was placed as a PDF file on the WWW site. This has been accepted for publication in an International Atomic Energy Agency TEC-DOC. It was written by invitation of the International Atomic Energy Agency for the Consultants Meeting on Three Methods of Soil Water Content Assessment, which Steve attended in Vienna, Austria, on Nov. 22-25, 1998.

Recent Publications (since Nov. 1998) . . .

Evett, S.R. 1999. Some Aspects of Time Domain Reflectometry (TDR), Neutron Scattering, and Capacitance Methods of Soil Water Content Measurement. International Atomic Energy Agency TEC-DOC. [in press]

Evett, S.R. 1999. Energy and Water Balances at Soil-Plant-Atmosphere Interfaces, Chapter 5 in the CRC *Handbook of Soil Science*. [in press]

Evett, S.R., F.H. Peters, O.R. Jones, and P.W. Unger. 1999. Soil hydraulic conductivity and retention curves from tension infiltrometer and laboratory data. *In Proc. of the International Workshop on the Characterization and Measurement of the Hydraulic Properties of Unsaturated Porous Media*, Oct. 22-24, 1997, Riverside, CA. [in press]

Marek, T.H., L.L. New, T.A. Howell, D. Dusek, G. Fipps, and J. Sweeten. 1998. Potential evapotranspiration networks in Texas: Design, coverage and operation. pp. 115-124. *In* Ric Jensen (ed.) *Proc. of the 25th Water for Texas Conference, "Water Planning Strategies for Senate Bill 1,"* Dec. 1-2, Austin, TX, Texas Water Resources Institute, Texas A&M University, College Station, TX.

Schneider, A.D., and T.A. Howell. 1999. LEPA and spray irrigation for grain crops. Amer. Soc. of Civil Engr. J. of Irrig. and Drain. Engr. [in press]

Tolk, J.A., T.A. Howell, and S.R. Evett. 1999. Effect of mulch, irrigation, and soil type on water use and yield of maize. Soil and Tillage Research 50 (2):137-147.

Unger, P.W., and T.A. Howell. 1999. Agricultural water conservation – a global perspective. J. of Crop Production [special issue on "*Water Use in Crop Production*," M.B. Kirkham (ed.)] [in press]

Yazar, A., T.A. Howell, D.A. Dusek, and K.S. Copeland. 1999. Evaluation of crop water stress index for LEPA irrigated corn. Irrig. Sci. [in press]

Personnel News . . .

Judy Tolk attended the Team Building and Team Leadership training OPM course in Aurora, CO, Nov. 30–Dec. 4, 1998.

Ron Allen has almost recovered from the defeat of his beloved KSU Wildcats in a thrilling come from behind, double-overtime football victory by the **Texas Aggies** in the Big XII Conference title game. **Judy Tolk** has given **Terry** and **Arland** grief, though, with her Hook 'em sign for that narrow two point victory (by a "foot") in Austin. **Husker Jim** (Dr. Jim Gilley) has been unusually quiet waiting for "next year."

Steve Evett and **Terry Howell** participated in the Space-State training workshop along with Louis Baumhardt in Lubbock, TX, Nov. 30–Dec. 2, 1998.

Judy Tolk and Priscilla Sheets (Steve's wife) had surgery in January and have now fully recovered.

Terry Howell attended the ASCE WRE Awards Committee Meeting in Davis, CA, Jan. 28, 1999.

Rick Todd, Arland Schneider, and **Terry Howell** attended the Central Plains Irrigation Meeting in Sterling, CO, from March 9–10, 1999.

Rick Todd traveled to Egypt from February 14–25, 1999, for the ATUT Project. He installed new software and maintained the TDR equipment, installed a new net radiometer, and did other routine inspection and maintenance on the weather station at Ismailia, collected data, and presented a seminar and technical report to ATUT.

Arland Schneider and **Terry Howell** attended the Kansas Water Conference in Manhattan, KS, on March 2–3, 1999.

Terry Howell participated in the Ph.D. Qualifying Examination of Qingwu Xue at the University of Nebraska on March 4, 1999.

Terry Howell and **Carole Perryman** represented the WMRU at the 1999 ARS Southern Plains Area Leadership Conference in Stuttgart, AR, Mar, 30–Apr. 1, 1999. **Don Dusek** attended the awards banquet on March 31, 1999. Also attending from Bushland were Nolan Clark, Bob Sears, and Rayma Cox.

Brice Ruthardt, biological technician (soils), was promoted and moved into a permanent position in the research unit. **WMRU** welcomes **Sara Ledbetter** back for her third summer (she works for ESAWRU during the winter) along with our new summer employee, **Wade Davis,** who is a WTAMU student. **Gary Marek** and **Kyle Schniederjan** both worked for WMRU part-time during the school year and are now on full-time during the summer.

Terry Howell was elected as chair-elect of ASA Division A-3, Agroclimatology & Agronomic Modeling for 1998-99 and will be A-3 Chair in 1999-2000 with program responsibilities for the 2000 meeting in Minneapolis, MN. He completed his assignment as chair of the Feasibility Committee for Agronomy Monograph No. 30, which was authorized for updating by the ASA/CSSA/SSSA Board of Directors.

Terry Howell, **Judy Tolk**, **Arland Schneider**, and **Carole Perryman** from WMRU along with Paul Unger and Rayma Cox attended a workshop on "Mistake-Free Grammar and Proofreading" in Amarillo on May 17, 1999.

Jack Musick continues to battle cancer and related health problems. His address is 5502 Floyd in Amarillo, TX 79106 [home phone is (806) 352-7549].

Water Management Research Unit

http://www.cprl.ars.usda.gov

RESEARCH STAFF

Dr. Terry A. Howell, P.E.
Research Leader (Agric. Engr.)
(806) 356-5746
tahowell@ag.gov

Dr. Steven R. Evett
Soil Scientist
(806) 356-5775
srevett@ag.gov

Ronald R. Allen
Collaborator (Agric. Engr.)
(806) 356-5725

Dr. Arland D. Schneider, P.E.
Agricultural Engineer
(806) 356-5732
aschneid@ag.gov

Dr. R. Nolan Clark
Laboratory Director (Agric. Engr.)
(806) 356-5734
rnclark@ag.gov

Dr. Richard W. Todd
Plant Physiologist
(806) 356-5728
rtodd@ag.gov

Karen S. Copeland
Soil Scientist
(806) 356-5735
kscopel@ag.gov

Dr. Judy A. Tolk
Plant Physiologist
(806) 356-5736
jtolk@ag.gov

Donald A. Dusek
Agronomist
(806) 356-5747

USDA United States Department of Agriculture

ars Agricultural Research Service

USDA-ARS
P.O. Drawer 10
Bushland, TX 79012-0010

POSTMASTER: Send address changes to *Wetting Front*, USDA-ARS, P.O. Drawer 10 Bushland, TX 79012-0010.

U.S. Postage